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Title: A Re-Analysis of Historical Los Alamos Critical Assembly Reaction Rate Measurements

Author(s): Kahler, Albert C. III
MacInnes, Michael
Chadwick, Mark B.

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A Re-Analysis of Historical Los Alamos Critical Assembly Reaction Rate Measurements

A.C. (Skip) Kahler, M. MacInnes, M.B.Chadwick

Los Alamos National Laboratory

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Introduction

- Benchmark Descriptions
  - Godiva, Jezebel, Flattop-25 & -Pu, Big-10
- Cross Section Processing
- Flux Spectra
- Calculated & Experimental Results
  - Using ENDF/B-VII.1 & IRDFF-v1.03
- Final Observations

GODIVA

- HEU-MET-FAST-001.
- ~94 w/o ^{235}U.
- Benchmark model is a simple, one material, sphere.
- Foil activation and fission chamber measurements made near the core center.

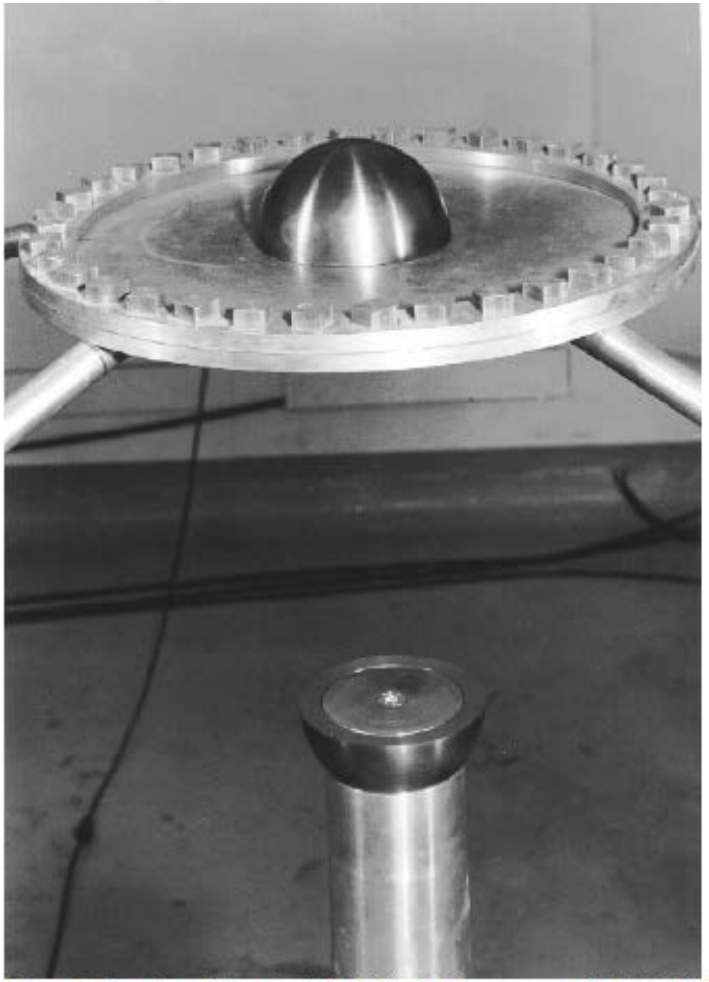


Figure 1. Experimental Setup for the Multiplication Measurements of Spherical Shell Configurations.

FLATTOP-25

- HEU-MET-FAST-028.
- Spherical HEU “core”.
- Spherical ^{nat}U reflector.
- Foil activation and fission chamber measurements made near the core center and for a radial traverse extending into the reflector.

Figure 5. The Flattop Assembly.

JEZEBEL

- Pu-MET-FAST-001.
- Revision 3 added to the ICSBEP Handbook in 2013.
- Benchmark model used here is a simple, one material, sphere.
- Foil activation and fission chamber measurements made near the core center.

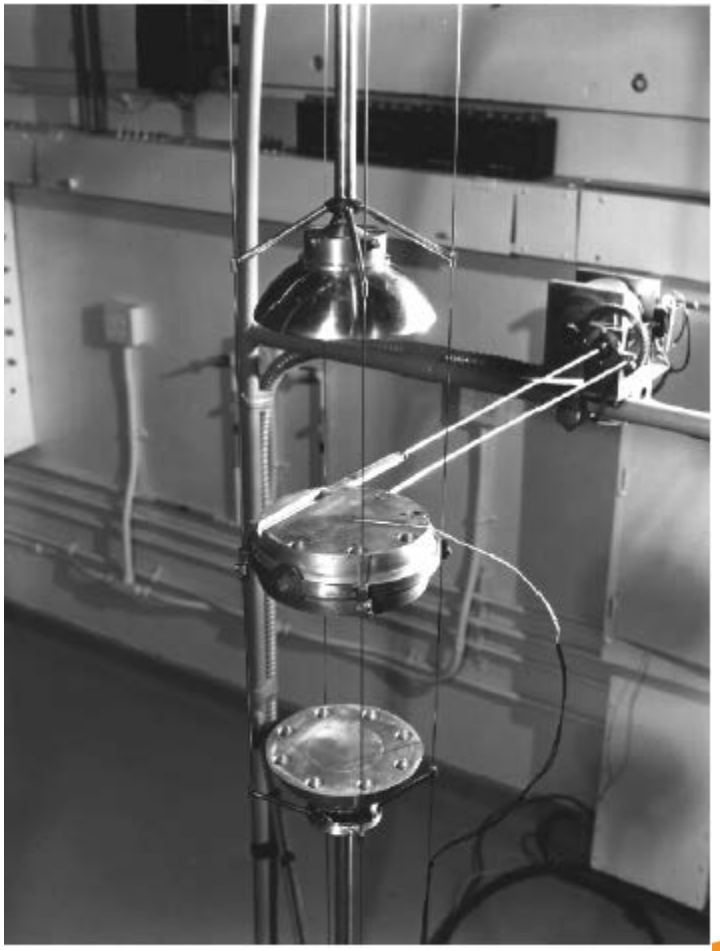


Figure 1. Jezebel in the "Safe" Configuration.*

FLATTOP-Pu

- Pu-MET-FAST-006
- Spherical Pu “core”.
- Spherical ^{nat}U reflector.
- Foil activation and fission chamber measurements made near the core center.

Figure 5. The Flattop Assembly.

Big-10

- IMF-MET-FAST-007.
- A large, heterogeneous uranium critical assembly.
- Benchmark model used here is a detailed plate-by-plate cylinder.
- Foil activation and fission chamber measurements made near the core center.

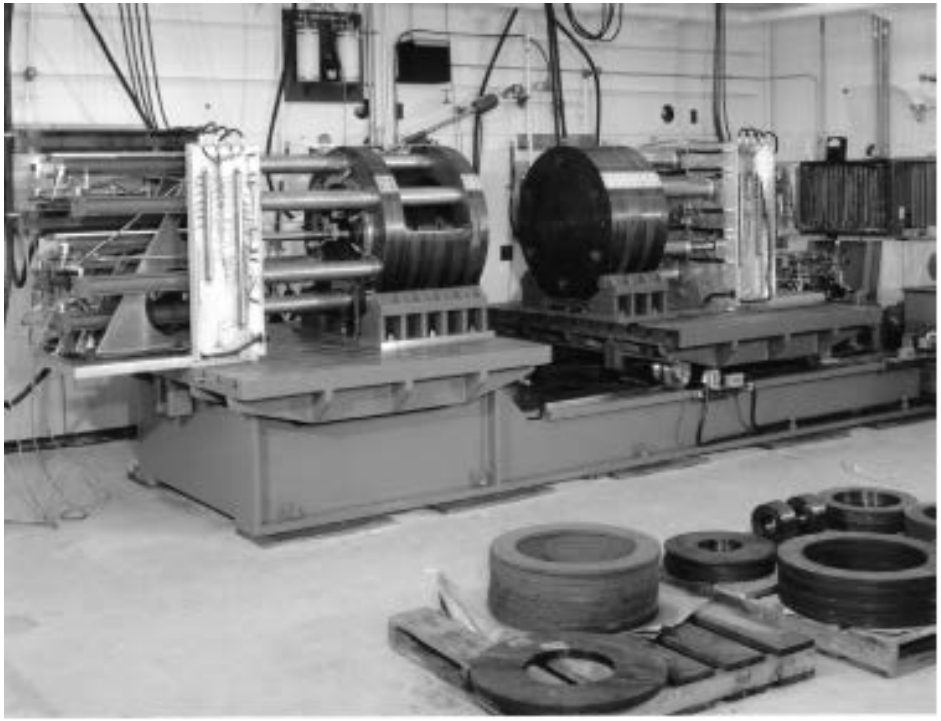


Figure 1. The Big Ten Assembly during Construction (1968).

Measurement Summary - I

- LANL critical assembly reaction rate measurements were made during the 1950s to 1970s
  - Until recently much of this data could only be found in internal LANL memoranda
  - Now becoming available in peer-reviewed literature
    - ENDF/B-VII.0 & VII.1 NDS 2006 & 2011 “Big Papers”;
    - P.G.Young *et al*, NDS **108**, 2589(2007);
    - ND2013 Proceedings (Chadwick *et al*).

Measurement Summary - II

- LANL critical assembly reaction rate measure-ments were made during the 1950s to 1970s
  - Reported results depend upon the “known” 14.1 MeV cross section at that time.

Reaction	Pre-1963	Post-1963	ENDF/B-7.1
$^{45}Sc(n,2n)^{44m}Sc$	0.115	0.105	0.104
$^{51}V(n,a)^{48}Sc$	0.0157		0.0152
$^{75}As(n,2n)^{74}As$	1.050		0.994
$^{89}Y(n,2n)^{88}Y$	0.670	0.845	0.850
$^{90}Zr(n,2n)^{89}Zr$	0.643	0.590	0.617
$^{103}Rh(n,2n)^{102m}Rh$	0.750	0.783	0.741
$^{107}Ag(n,2n)^{106m}Ag$		0.573	0.520
$^{169}Tm(n,2n)^{168}Tm$		1.96	1.980
$^{175}Lu(n,2n)^{174}Lu$		1.789	2.122
$^{191}Ir(n,2n)^{190x}Ir$		1.995	2.066
$^{197}Au(n,2n)^{196}Au$		2.214	2.132
$^{203}Tl(n,2n)^{202}Tl$	1.428	2.090	2.005
$^{204}Pb(n,2n)^{203}Pb$	1.746		2.193
$^{238}U(n,2n)^{237}U$		0.895	0.850

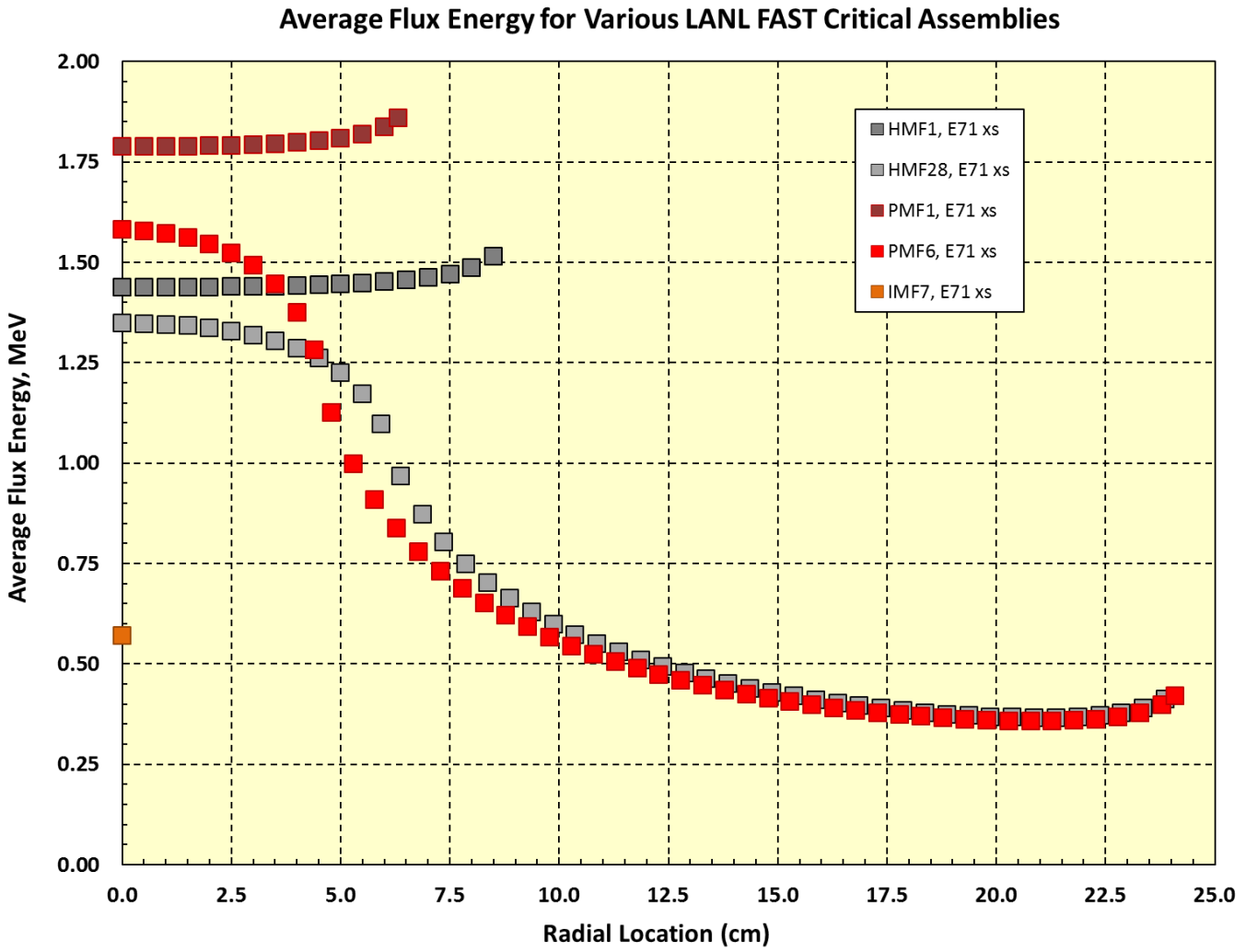
Cross Section Processing

- ENDF/B-VII.1 results use the .80c cross sections distributed with MCNP6.1
- IRDFF-v1.03 results use MCNP “dosimetry” class (.##y) files processed at LANL with NJOY.
  - IRDFF files are in a pointwise format and already Doppler broadened to 300K
  - Only need to run NJOY’s “ACER” module
    - Linearization is NOT necessary

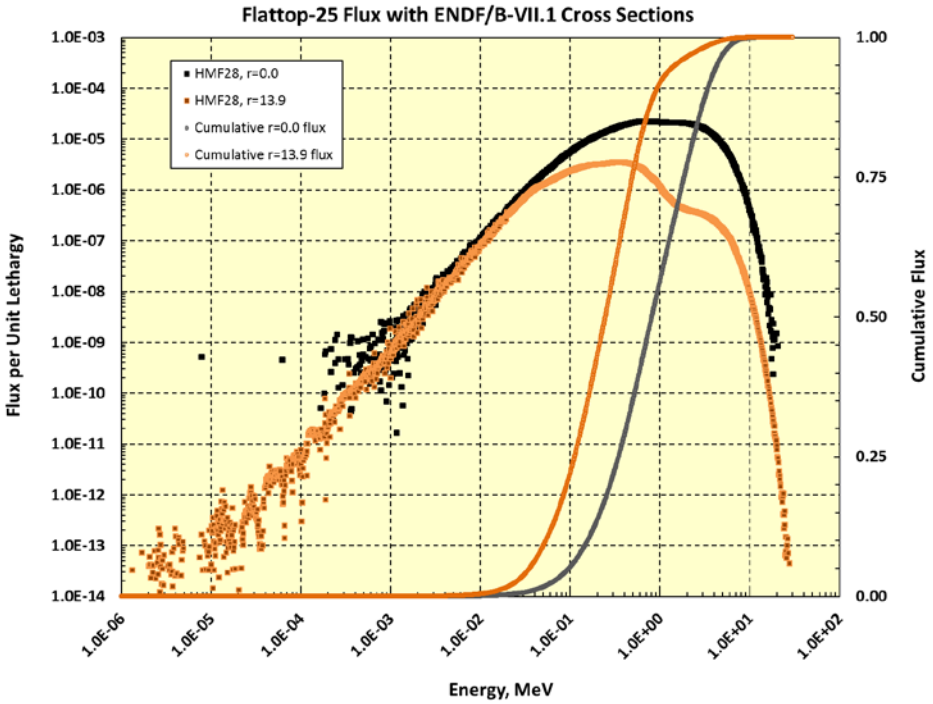
MCNP6 Calculation Strategy

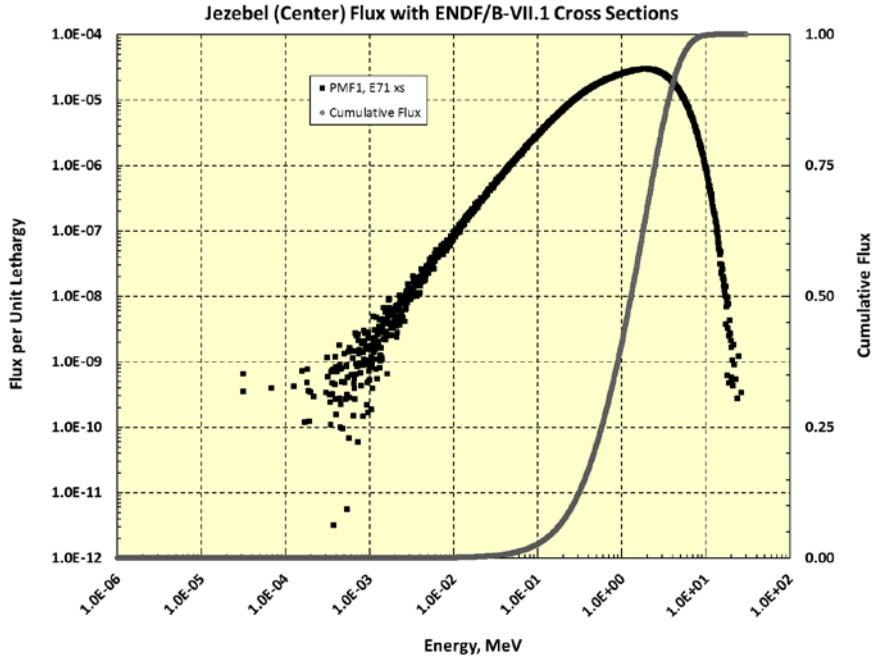
- Run 10 independent 500M neutron history jobs
  - 100,000 histories per cycle, 5,000 cycles plus 25 “warm-up cycles.
- Define tally regions for
  - 0.5 cm diameter central sphere;
  - 0.5 cm thick shells with increasing radius.
- Save “mctal” file for each job.
- Use the supplied “merge_mctal.pl” utility to combine the 10 mctal files.

Critical Assembly Average Flux Energy - I



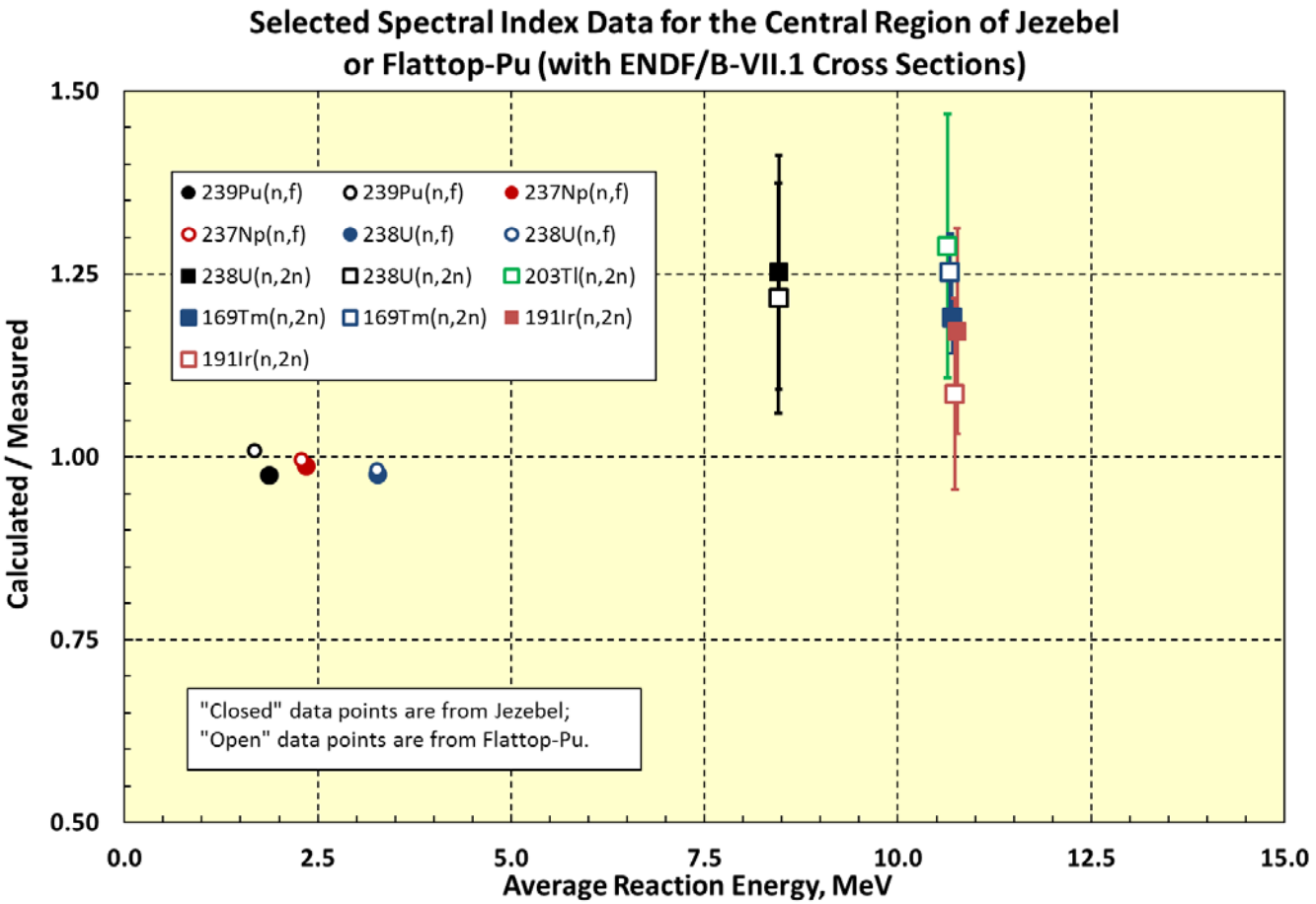
Critical Assembly Average Flux Energy - II





Critical assembly flux distributions are nowhere near mono-energetic; rather they span hundreds of keV/MeV.

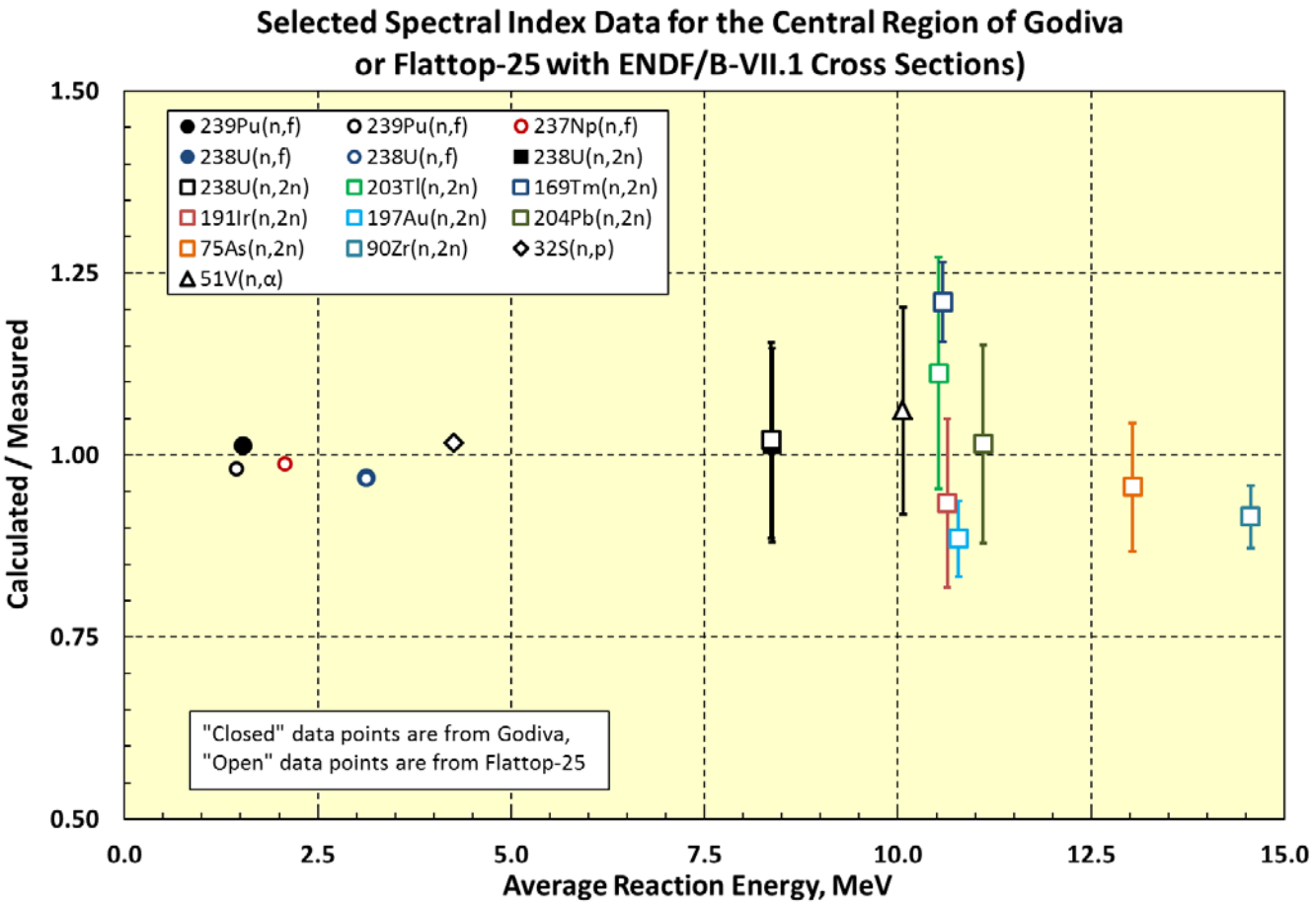
Jezebel & Flattop-Pu Results



Near unity C/E results are seen at low energies for ^{238}U, ^{237}Np & ^{239}Pu (n,f) spectral indicies.

C/E's seem biased high at larger average reaction rate energies … but pfns uncertainties are not included.

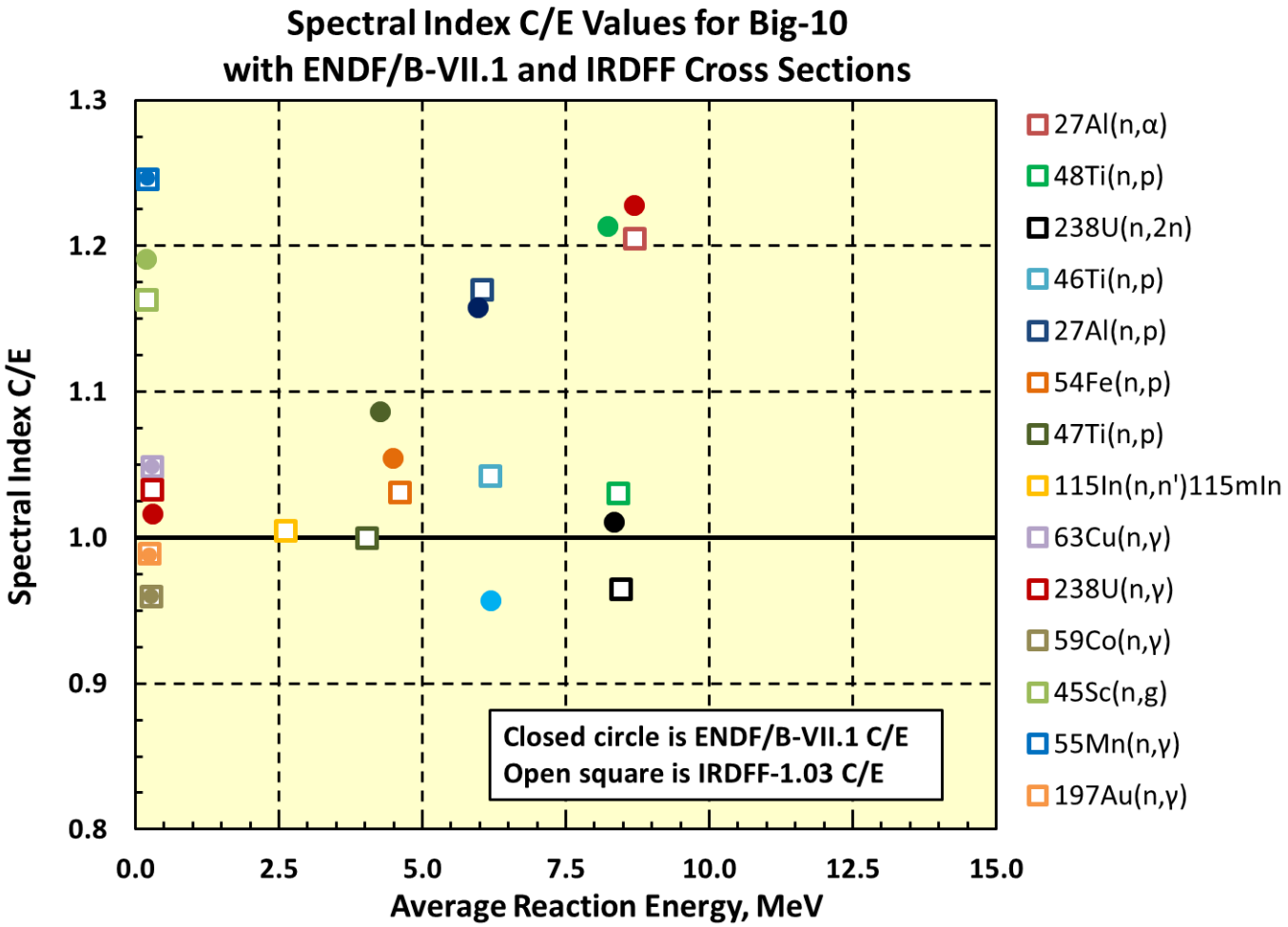
Godiva & Flattop-25 Results



Near unity C/E results are seen at low energies for ^{238}U, ^{237}Np & ^{239}Pu (n,f) and $^{32}S(n,p)$ spectral indicies.

In contrast to Pu fuelled critical assemblies, these C/E's remain near unity throughout the measured energy range.

Big-10 Results



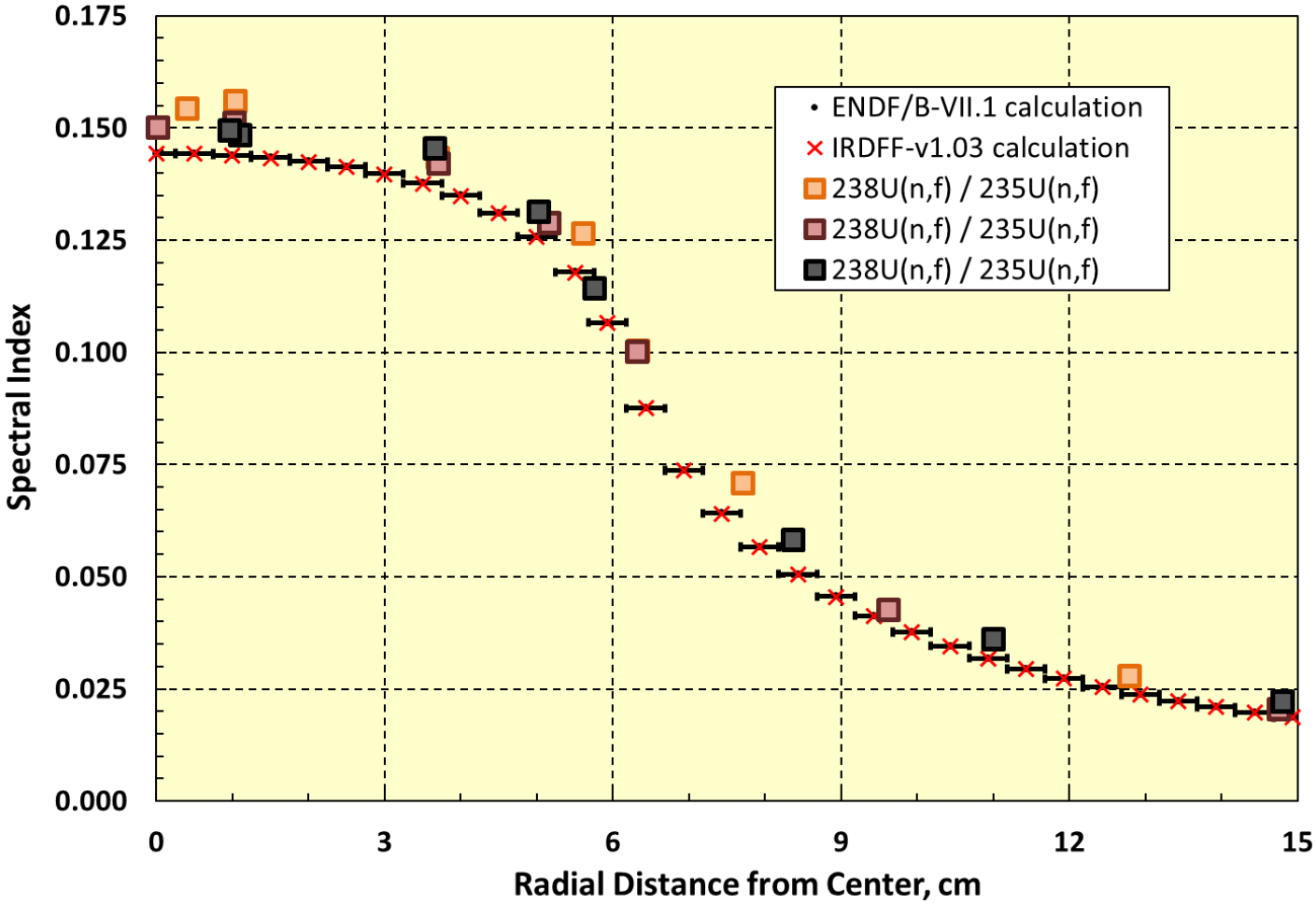
E71=open square.

IRDFF-v1.03=closed circle.

Capture reactions, such as $^{45}Sc(n,\gamma)$ and $^{55}Mn(n,\gamma)$ need further review.

Large differences between ENDF and IRDFF need further review … ^{45}Sc, $^{46,48}Ti$.

^{238}U(n,f) Spectral Index in Flattop-25

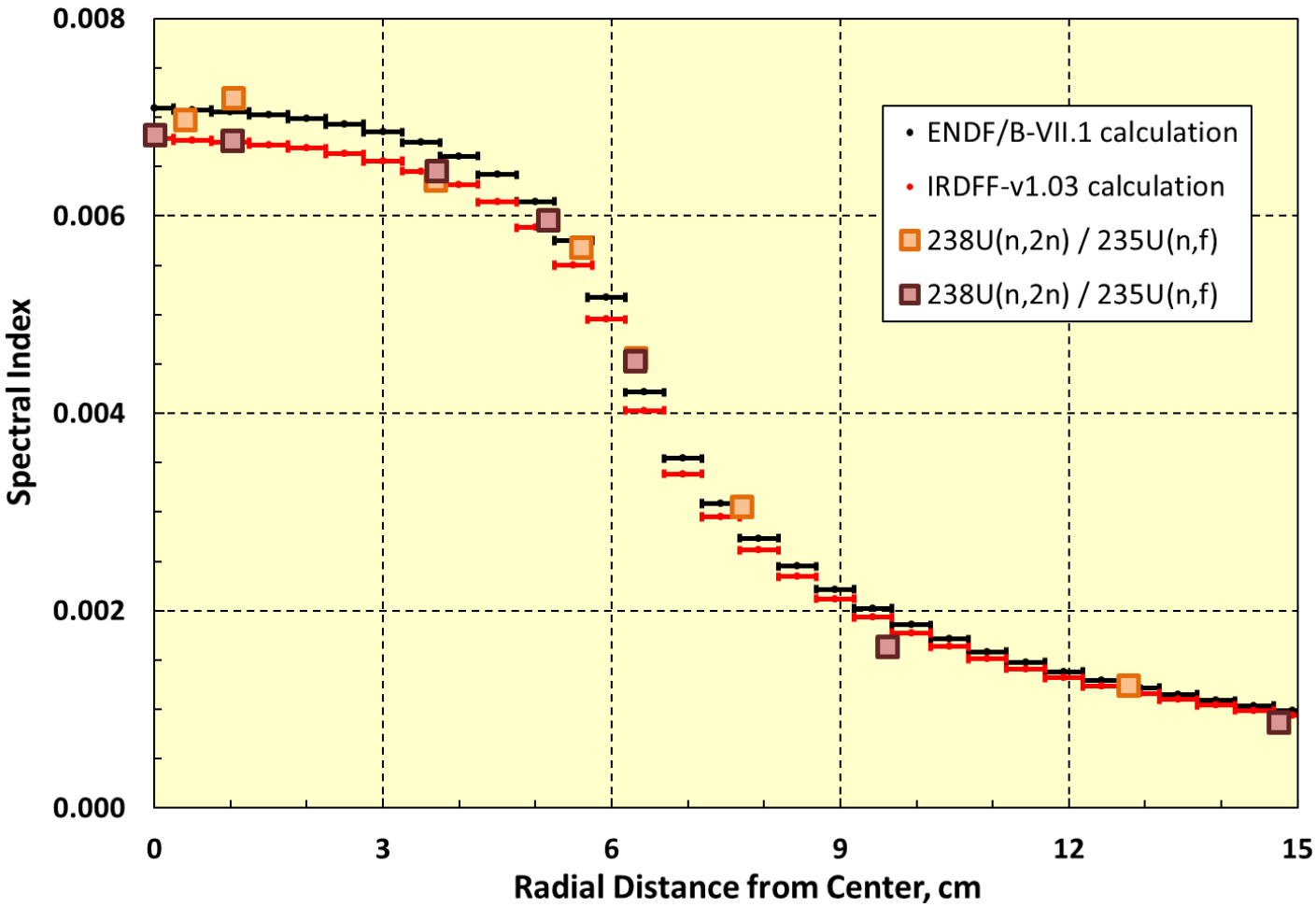


^{238}U(n,f) spectral index versus radius in Flattop-25.

Horizontal "error bars" denote radial shell tally (with ENDF/B).

*"**x**" is IRDFF-v1.03 .*

^{238}U(n,2n) Spectral Index in Flattop-25



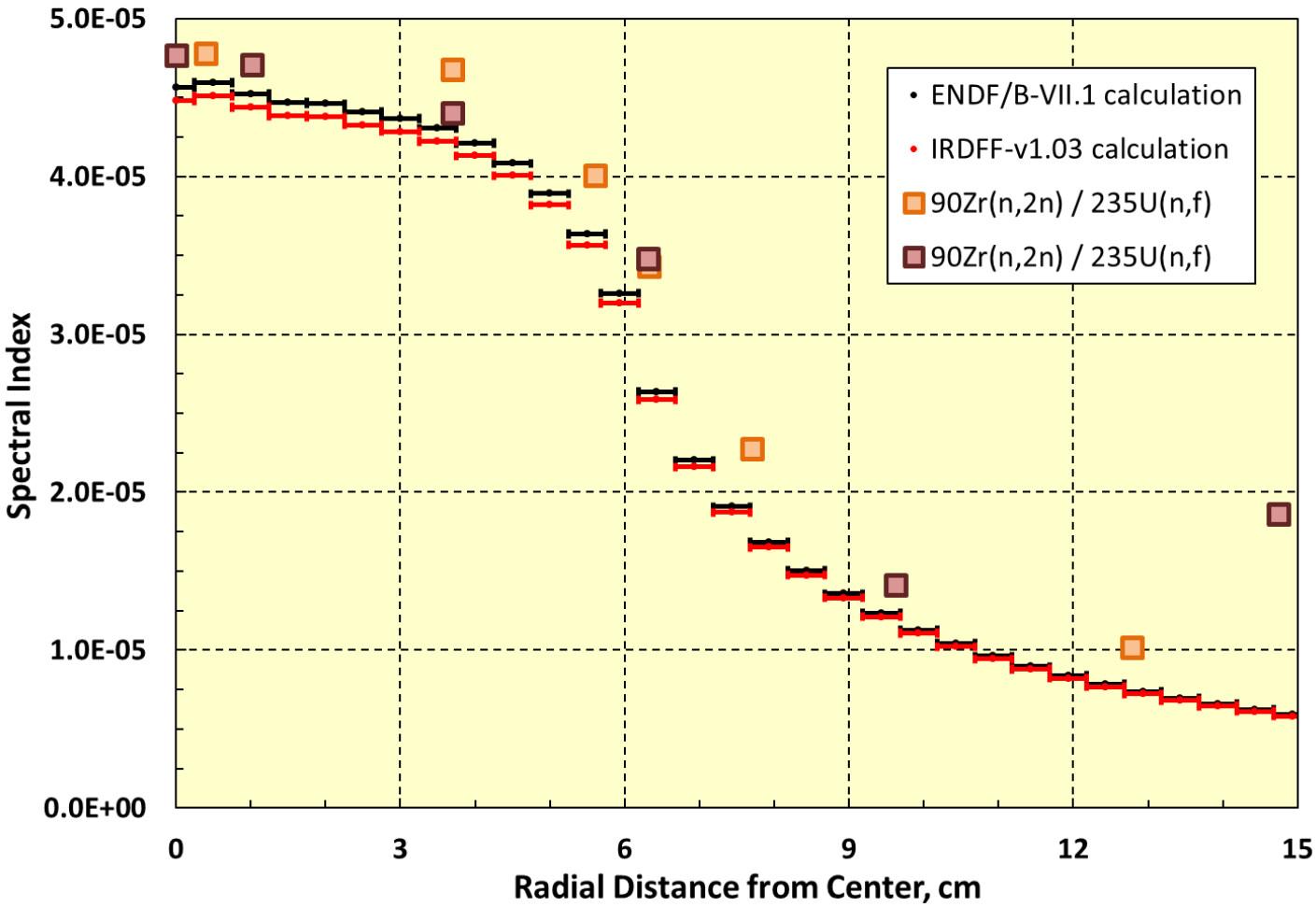
^{238}U(n,2n) spectral index versus radius in Flattop-25.

Horizontal "error bars" denote radial shell tally (with ENDF/B).

*"**x**" is IRDFF-v1.03 .*

There is a clear difference between ENDF and IRDFF

^{90}Zr(n,2n) Spectral Index in Flattop-25



One of the highest average energy reactions … there is a clear C/E < 1 bias for all radii.

Outermost radial measurement seems anomalous.

Final Observations

- Not conclusions, as the story is clearly not complete …
  - pfns studies remain a work in progress
    - An IAEA CRP on this topic has yet to reach a consensus.
  - New measurements and advanced fission theory work continues at LANL.
  - Differences among major cross section libraries remains an unresolved issue (but we're working on it … e.g. the WPEC "CIELO" Project).